

IN THE CLAIMS:

Claim 1. (Currently Amended) An apparatus for controlling a salient-pole DC brushless motor having armatures in three phases, comprising:

voltage applying means for applying drive voltages to said armatures;

high-frequency adding means for adding high-frequency voltages to said drive voltages;

first current detecting means for detecting a current flowing through an armature in a first phase of said armatures in the three phases;

second current detecting means for detecting a current flowing through an armature in a second phase of said armatures in the three phases;

reference value extracting means for extracting a sine reference value depending on the sine value of a twofold angle which is twice a rotor angle of said motor and a cosine reference value depending on the cosine value of the twofold angle, using a first current value detected by said first current detecting means and a second current value detected by said second current detecting means when said high-frequency voltages are added to said drive voltages by said high-frequency adding means, and high-frequency components depending on said high-frequency voltages;

rotor angle calculating means for calculating a rotor angle of said motor using said sine reference value and said cosine reference value;

three-phase/dq converting means for handling said motor as an equivalent circuit having a q-axis armature disposed on an a q-axis in the direction of magnetic fluxes from a rotor of the motor and a d-axis armature disposed on a d-axis which is perpendicular to the q-axis, and calculating a detected q-axis current flowing through

said q-axis armature and a detected d-axis current flowing through said d-axis armature based on the rotor angle of said motor which is calculated by said rotor angle calculating means, said first current value, and said second current value;

current control means for determining said drive voltages in order to eliminate a q-axis current difference which is the difference between the detected q-axis current and a predetermined q-axis command current and a d-axis current difference which is the difference between the detected d-axis current and a predetermined d-axis command current; and

magnetic pole detecting means for carrying out a magnetic pole detecting process to detect the orientation of the magnetic poles of said rotor based on a magnetic pole reference value calculated by a predetermined calculating process, depending on said sine reference value and said cosine reference value which are extracted by said reference value extracting means when said q-axis command value current is set to a predetermined magnetic pole detecting current;

said current control means comprising means for performing a proportional plus integral process on the difference between said detected q-axis current and said q-axis command current to calculate said q-axis current difference and also performing a proportional plus integral process on the difference between said detected d-axis current and said d-axis command current to calculate said d-axis current difference when said magnetic pole detecting process is not carried out, and performing an integral process only on the difference between said detected q-axis current and said q-axis command current to calculate said q-axis current difference and also performing an integral process only on the difference between said detected d-axis current and said d-

axis command current to calculate said d-axis current difference when said magnetic pole detecting process is carried out.

Claim 2. (Original) An apparatus according to claim 1, wherein said magnetic pole detecting means comprises means for setting a first magnetic pole detecting current and a second magnetic pole detecting current which is opposite in direction to said first magnetic pole detecting current as said magnetic pole detecting current, and detecting the orientation of the magnetic poles of said rotor based on the difference between a first magnetic pole reference value calculated by said predetermined calculating process depending on said sine reference value and said cosine reference value which are extracted by said reference value extracting means when said first magnetic pole detecting current is set, and a second magnetic pole reference value calculated by said predetermined calculating process depending on said sine reference value and said cosine reference value which are extracted by said reference value extracting means when said second magnetic pole detecting current is set.

Claim 3. (Original) An apparatus according to claim 1, wherein said reference value extracting means comprises means for extracting said sine reference value and said cosine reference value respectively according to the following equations (19), (20):

$$V_s = \int_0^{2\pi} \left\{ \cos 2\omega t \cos (\omega t + \frac{2}{3}\pi) \cdot I_u - \cos 2\omega t \cos \omega t \cdot I_w \right\} dt \quad \cdots (19)$$

$$V_c = - \int_0^{2\pi} \left\{ \sin 2\omega t \cos (\omega t + \frac{2}{3}\pi) \cdot I_u - \sin 2\omega t \cos \omega t \cdot I_w \right\} dt \quad \cdots (20)$$

where Vs: the sine reference value, Vc: the cosine reference value, Iu: the first current value, Iw: the second current value, and ω : the angular velocity of said high-frequency voltages.

Claim 4. (New) A method for controlling a salient-pole DC brushless motor having armatures in three phases, wherein an apparatus for controlling said DC brushless motor comprises:

voltage applying means for applying drive voltages to said armatures;
high-frequency adding means for adding high-frequency voltages to said drive voltages;
first current detecting means for detecting a current flowing through an armature in a first phase of said armatures in the three phases;
second current detecting means for detecting a current flowing through an armature in a second phase of said armatures in the three phases;
reference value extracting means for extracting a sine reference value depending on the sine value of a twofold angle which is twice a rotor angle of said motor and a cosine reference value depending on the cosine value of the twofold angle, using a first current value detected by said first current detecting means and a second current value detected by said second current detecting means when said high-frequency voltages are added to said drive voltages by said high-frequency adding means, and high-frequency components depending on said high-frequency voltages;

rotor angle calculating means for calculating a rotor angle of said motor using said sine reference value and said cosine reference value; and

three-phase/dg converting means for handling said motor as an equivalent circuit having a q-axis armature disposed on a q-axis in the direction of magnetic fluxes from a rotor of the motor and a d-axis armature disposed on a d-axis which is perpendicular to the q-axis, and calculating a detected q-axis current flowing through said q-axis armature and a detected d-axis current flowing through said d-axis armature based on the rotor angle of said motor which is calculated by said rotor angle calculating means, said first current value, and said second current value;

wherein said method comprises the step of:

determining said drive voltages in order to eliminate a q-axis current difference which is the difference between the detected q-axis current and a predetermined q-axis command current and a d-axis current difference which is the difference between the detected d-axis current and a predetermined d-axis command current;

performing a magnetic pole determination process for detecting the orientation of the magnetic poles of said rotor based on a magnetic pole reference value calculated by a predetermined calculating process, depending on said sine reference value and said cosine reference value which are extracted by said reference value extracting means when said q-axis command current is set to a predetermined magnetic pole detecting current; and

performing a proportional plus integral process on the difference between said detected q-axis current and said q-axis command current to calculate said q-axis current difference and also performing a proportional plus integral process on the

difference between said detected d-axis current and said d-axis command current to calculate said d-axis current difference when said magnetic pole detecting process is not performed, and performing an integral process only on the difference between said detected q-axis current and said q-axis command current to calculate said q-axis current difference and also performing an integral process only on the difference between said detected d-axis current and said d-axis command current to calculate said d-axis current difference when said magnetic pole detecting process is performed.

Claim 5. (New) A method according to claim 4, further comprising the step of setting a first magnetic pole detecting current and a second magnetic pole detecting current, which is opposite in direction to said first magnetic pole detecting current as said magnetic pole detecting current, said step of performing the magnetic pole determination process comprising the step of:

detecting the orientation of the magnetic poles of said rotor based on the difference between a first magnetic pole reference value calculated by said predetermined calculating process depending on said sine reference value and said cosine reference value which are extracted by said reference value extracting means when said first magnetic pole detecting current is set, and a second magnetic pole reference value calculated by said predetermined calculating process depending on said sine reference value and said cosine reference value which are extracted by said reference value extracting means when said second magnetic pole detecting current is set.

Claim 6. (New) A method according to claim 1, wherein said reference value extracting means comprises means for extracting said sine reference value and said cosine reference value respectively according to the following equations (21), (22):

$$V_s = \int_0^{\frac{2\pi}{\omega}} \left\{ \cos 2\omega t \cos (\omega t + \frac{2}{3}\pi) \cdot I_u - \cos 2\omega t \cos \omega t \cdot I_w \right\} dt \quad \cdots(21)$$

$$V_c = - \int_0^{\frac{2\pi}{\omega}} \left\{ \sin 2\omega t \cos (\omega t + \frac{2}{3}\pi) \cdot I_u - \sin 2\omega t \cos \omega t \cdot I_w \right\} dt \quad \cdots(22)$$

where Vs: the sine reference value, Vc: the cosine reference value, Iu: the first current value, Iw: the second current value, and ω : the angular velocity of said high-frequency voltages.